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**TITLE: BOLTED CONNECTOR FOR ELECTRICAL
EQUIPMENT**

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BOLTED CONNECTOR FOR ELECTRICAL EQUIPMENT

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

- [1] The present invention relates generally to mechanical-electrical connectors, and, more specifically, the present invention relates to a bolted mechanical connector for continuously wound electrical machines.

2. DESCRIPTION OF THE BACKGROUND

- [2] Electrical machines such as generators and motors (collectively "machines") basically consist of current-carrying electrical conductors assembled in slots in iron cores. To construct a practical machine, these electrical conductors must be connected together or "networked" to form functional electric circuits. The interconnection of segments of these electrical circuits may take on many different forms.
- [3] Typically, small to medium-sized machines use simple crimp-type hardware, brazing, or soldered joints to produce the connections required to form the circuits. These are relatively simple joint problems which are solved with a permanent or semi-permanent joint solution.
- [4] Generally speaking, the required complexity of the conductors, circuits, and connections are determined by the type, size, or rating of the particular motor or generator. Essentially, the larger the machine, the

more complex the joint configuration and the conductor system geometry become. For example, as the size of the machine increases, the individual slot conductor, referred to here as a conductor bar, becomes a system of several individually insulated conductor strands in parallel within the single conductor bar.

[5] **FIG. 4** depicts a typical conductor bar **300** with eight individual insulated conductors **305** surrounded by an outer insulated wrapping **310**. Typically, the orientation would be used to form four "conductor-pairs" **320** (each one represented by a row in **FIG. 4**), that may each be at the same or a different electrical potential. The increased conductor complexity of these larger machines generates requirements for a more complicated connector to maintain the integrity of separations of the individual insulated strands within each conductor bar.

[6] Small machines with round, single-piece stator cores utilize electrical conductor circuit connectors that reside within a single one-piece stator. Most, if not all electrical connections can be, and are traditionally, made in the factory. However, larger continuously wound electrical machines, like "water wheel generators" and long linear motors, are fabricated in and transported from the factory to the field erection site (or any site at which they are subsequently put together) in several segments or sections. The largest or longest length that can be transported (often determined by truck size or load weight limitations) will determine the length or size of each stator section. Longer, larger motors require a greater number of sections. As described in more detail

below and as used as an exemplary machine for which to describe the present invention, **FIGS. 1** and **2** depict a two-section stator continuously wound linear motor with required interconnections both before (**FIG. 1**) and after assembly, before electrical connection (**FIG. 2**).

[7] This type of motor interface requires reliable, efficient conductor connections between each conductor of each successive stator section made at the assembly installation site. In all machines, efficient electrical joint design is required. This design effort entails maximizing the efficiency of the use of available space by minimizing the size of the connector. The connector design must include features to minimize the size, weight, and installation time.

[8] As a partial solution, in applications not requiring ease of maintainability, minimization of field assembly time, or rapid "spare section" replacement, the electrical connection between successive stator conductors can be accomplished by making the circuit connections using weld, braze, or solder metals joining, followed by applying the required strand and outer insulation by hand. A second method sometimes used is to "bridge the interface" between sections by shipping the sections with empty slots adjacent to the section-to-section interfaces and filling these slots with field-wound full diamond coils. This method also requires "scarce craft skills" (expert knowledge and training) to wind the coils in the empty slots and complete the other required connection tasks.

[9] Both of these traditional methods suffer from undesired characteristics including: limited maintainability,

complicated refurbishment of spare part replacement, and required scarce craft skills to perform the connection work. Reliability of work performed out of the factory environment can also add unknown risks to equipment performance.

- [10] As such, there is a need in the art to provide a mechanical-electrical connector for these large, multi-sectioned stator machines that facilitates ease of assembly and replacement at the installation site, while meeting the desired electrical and mechanical specifications set forth for the machine. The present invention, in at least one preferred embodiment, addresses one or more of the above-described and other limitations to prior art systems.

SUMMARY OF THE INVENTION

- [11] In accordance with at least one preferred embodiment, the present invention provides a mechanical-assembled fastener capable of providing multiple-circuit electrical connections. The connector is preferably designed to occupy minimum physical space while maintaining electrical circuit integrity when joining multiple electrical circuits in applications requiring the splicing of current-carrying electrical conductors (round, rectangular, hollow, etc.) in electrical machines (stationary, rotating, linear, etc.).
- [12] In one exemplary embodiment, the connector is used as part of a long linear motor comprised of wound sections that require connection between end coils bridging

adjacent sections. The end pieces of the main coil sections (half-diamond sections) are machined to easily accept the electrical-mechanical connector. The connector provides a mechanical and electrical connection between the conductors of the main coil sections while maintaining designed operating conditions.

- [13] The present invention preferably provides efficient assembly, disassembly, and maintenance of electrical machinery without the use of "semi-permanent" welded, brazed, soldered, riveted, and similar metals joining processes. The mechanical-electrical connector also facilitates connection of multiple electrical circuits using a single fastener and maintains electrical strike and creep integrity between electrical circuits of different potentials, as in a series coil. The connector also preferably minimizes physical space required to make single multi-strand connections and allows for the incorporation of electrical Roebel transposition within the connector.

BRIEF DESCRIPTION OF THE DRAWINGS

- [14] For the present invention to be clearly understood and readily practiced, the present invention will be described in conjunction with the following figures, wherein like reference characters designate the same or similar elements, which figures are incorporated into and constitute a part of the specification, wherein:

- [15] **Figure 1** depicts a two-section linear motor interface before assembly;

- [16] **Figure 2** depicts a two-section linear motor with both sections pushed in place next to each other;
- [17] **Figure 3** shows a front (**3A**), top (**3B**) and side (**3C**) view of a conventional formed full-diamond coil;
- [18] **Figure 4** details a cross-section of a multi-conductor coil;
- [19] **Figure 5** depicts a top (**5A**) and side (**5B**) view of a formed upper half-diamond coil;
- [20] **Figure 6** depicts a top (**6A**) and side (**6B**) view of a formed lower half-diamond coil;
- [21] **Figure 7** depicts a top (**7A**) and side (**7B**) view of the upper and lower half-diamond coils combined to form a full-diamond coil, assembled according to the present invention;
- [22] **Figure 8** is an exploded view of exemplary coil end geometries for bolted series electrical connectors, including top (**8A**) and side (**8B**) views of a four conductor connector, and top (**8C**) and side (**8D**) views of a three conductor connector with phase lead;
- [23] **Figure 9** depicts a two-section linear motor connected according to the present invention;
- [24] **Figure 10** is a current circuit depicting the flow of current through each of the coils in the machine;
- [25] **Figure 11** depicts the assembly of exemplary bolted series connectors, including top (**11A-11C**), side (**11C**) and bottom (**11E**) views of a four conductor connector, and top (**11F-11H**), side (**11I**) and bottom

(11J) views of a three conductor connector with phase lead; and

- [26] **Figure 12** shows the assembled bolted series connector with insulating boots, including internal side views (12A-12B) and external bottom (12C), side (12D) and top (12E) views.

DETAILED DESCRIPTION OF THE INVENTION

- [27] It is to be understood that the figures and descriptions of the present invention have been simplified to illustrate elements that are relevant for a clear understanding of the invention, while eliminating, for purposes of clarity, other elements that may be well known. Those of ordinary skill in the art will recognize that other elements are desirable and/or required in order to implement the present invention. However, because such elements are well known in the art, and because they do not facilitate a better understanding of the present invention, a discussion of such elements is not provided herein. The detailed description will be provided hereinbelow with reference to the attached drawings.

- [28] As briefly described above, in various types of wound synchronous machines, the stator consists of a continuously wound conductor (or conductors) throughout the machine. In the case of a round machine, the stator loops are completely continuous, and in the case of a linear motor, the stator loops travel from one end of the machine to the other along the main axis.

[29] In most of these synchronous machines, the entire stator is manufactured as one single piece. However, in extremely large machines, the stator may need to be pieced or sectioned in order to transport the machine to its installation site (or for feasibility of manufacturing). For example, large linear motors and large water wheel-type round motors may require the stator to be sectioned. Upon installation, therefore, some mechanical and electrical connection must be implemented at each interconnection point between successive stator sections.

[30] The longest length of an individual electrical motor (or generator) stator section that can be transported typically determines the maximum practical factory-manufactured length of each individual stator section. These large stator sections are then field-assembled into a complete electrical machine. The conductors within the stator sections must be electrically connected together at the assembly site while maintaining the desired electrical and mechanical characteristics of the machine. A typical assembly of two of large stator sections is depicted in **FIG. 1** (before assembly) and **FIG. 2** (after assembly, before electrical connection). This assembly process produces a continuously wound linear motor after field installation (or assembly at any location) of some electrical and mechanical connector at the points at which the two stator sections meet.

[31] In **FIG. 1**, two stator sections (first stator section **105** and second stator section **107**) of a linear motor **100** are shown separated before installation. The stator in this particular linear motor **100** is made up of conductive

loops commonly referred to as formed full-diamond coils **110** (see **FIG. 3**). As shown in more detail in **FIG. 3B**, this name derives from the diamond shape of the loops **110** when viewed from above.

[32] In the present exemplary linear motor **100**, each of these full-diamond coils **110** includes four pairs of conductors (see **FIG. 4**, a cross-section of the coil). As described in more detail below, the conductors within the full-diamond coil **110** may be oriented in series such that current flows into the full-diamond coil **110** through one conductor pair, makes four complete loops around the full-diamond coil, and finally exits the full-diamond coil through another conductor-pair (to enter the next adjacent full-diamond coil). Each "row" **320** of two conductors **305** shown in **FIG. 4** would be at the same potential, and successive rows **320** would be wound in successive loops around the coil **110** (and would be at different potentials). A plurality of these full-diamond coils **110** are arranged successively down the long axis of the linear motor **100** with the entry and exit conductor pairs connected to each other such that the plurality of full-diamond coils form a continuous series of loops, or a continuous coil down the length of the linear motor. This stator orientation is common in the art.

[33] A problem arises, however, when the linear motor **100** (or large round motor) must be sectioned before installation because these continuous loops are interrupted at the joints between successive stator sections **105**, **107**. Further, this problem is aggravated when, as in the present example, each of the full-diamond coils **110** is

comprised of multiple conductors, as with the four conductor-pairs shown in **FIG. 4**.

- [34] In order to fabricate a sectioned stator as in **FIG. 1**, the full-diamond coils **110** must be specially fabricated to allow for eventual combination with successive stator sections at installation. The first stator section **105** is fabricated by laying successive full-diamond coils **110** (**FIG. 3**) next to each other, from right to left in **FIG. 1**, according to conventional practices. These full-diamond coils **110** are wound into the stator core **120**, connected to each other, and vacuum impregnated with resin prior to leaving the factory to maximize insulation between conductors.
- [35] However, when the section interface between the first **105** and second **107** stator sections is encountered, the bottom slots in the stator core **120** are no longer available in which to place full-diamond coils **110**. In other words, because of the angle at which the full-diamond coils **110** sit in the stator core **120**, these last few coil slots in the first stator section **105** can only accommodate the upper portion (opposite the stator core **120**) of a full-diamond coil **110**. The balance of the upper slots in the first stator section **105**, therefore, are filled with specially designed "upper half-diamond coils" **130**, similar to those shown in **FIG. 5**.
- [36] **FIG. 5** details a top view (**5A**) and side view (**5B**) of an upper half-diamond coil **130** for use with the present invention. In short, the upper half-diamond coil **130** is fabricated to mimic the upper portion of a full-diamond coil **110** (**FIG. 3**) with specially designed coil ends (or tips) **135** to accommodate interconnection with a lower

half-diamond coil **140** (described below). The details of these tips **135** are shown in an exploded view in **FIG. 8A** (top view of two exemplary tips) and **FIG. 8B** (side view of the same).

[37] Because the exemplary embodiment of the stator coils includes four conductor-pairs (**FIG. 4**), the tips **135** of the upper half-diamond coil **130** are arranged as four paired tips. Each of these tip-pairs has a hole **137** drilled there-through (see **FIG. 8A**) to accommodate a bolt **220** which secures the electrical-mechanical connector to the coils (described below). The tip pairs **135** are then arranged in four vertical rows (see **FIG. 8B**). These tips **135** exist on both sides of the upper half-diamond coil **130**.

[38] Returning to **FIG. 1**, the upper half-diamond coils **130** are successively installed into the first stator section **105** next to the previously described full-diamond coils **110**. The coil tips with exposed conductors extend out beyond the edge of the first stator section **105**.

[39] The fabrication of the next successive stator section (second stator section **107**) proceeds in a similar fashion. To mate with these upper slot half-diamond coils **130** in the first stator section **105** (when the two stator section are moved together in **FIG. 2**), lower half-diamond coils **140** (see **FIG. 6**) are placed in the lower slots of the stator core **120** at the right side of the second stator section **107** in **FIG. 1**. These lower half-diamond coils **140** are fabricated to mimic the lower part of the full-diamond coil **110** shown in **FIG. 3**. As with the upper half-diamond coil **130**, the conductor ends or tips on the left side of the lower half-diamond coil

140 are exposed and machined to form four paired conductor tips **135** (see **FIGS. 8A-8B**). However, it should be noted that the tip **145** on the right side of the lower half-diamond conductor **140** (see **FIGS. 8C-8D**) includes only three conductor-pairs. One conductor-pair **147** is left without machining so that it may be used to connect to the next successive half-diamond (or full-diamond) coil. This connection is described in more detail below.

[40] Turning back to **FIG. 1**, continuing in the fabrication of the second stator section **107** from right to left, the balance of the second stator section is filled with full-diamond coils **110**. At this point, there is sufficient room in both the stator core **120** and the upper portion of the stator to accommodate the full-diamond coil **110**. The number of upper half-diamond coils **130** in the first stator section **105** matches the number of lower half-diamond coils **140** in the second stator section **107** to accommodate interconnection.

[41] At the installation site, these two separate first **105** and second **107** stator sections are brought together as in **FIG. 2**. Note that the upper **130** and lower **140** half-diamond coils (each with four conductor-pairs) are now in place next to each other. In fact, the four conductor-pairs at the tip of the upper half-diamond coil **130** and the four (or three) conductor-pairs at the tip of the lower half-diamond coil **140** should now be aligned such that a bolt **220** may be passed through the "drilled-out" hole **137** through the tips **135**, **145** (see generally **FIG. 8**). This bolt **220** will secure the mechanical-electrical connector to the tips **135**, **145** of

the upper **130** and lower **140** half-diamond coils (see **FIG. 7B** and **10**).

[42] The tooling of the tips **135**, **145** of each of the half-diamond coils **130**, **140** preferably occurs at the fabrication plant. Prior to the factory winding of each half coil **130**, **140**, a workstation is used to produce the tip details. Two of the many tip configurations **135**, **145** available are shown in the top views of **FIGS. 8A** and **8C**. For example, a drilled semi-circle hole **137** replacing the slot would provide a locking notch and provide positive registration of the connector strap jumpers (see **FIG. 11** at **210**), ensuring proper axial placement during assembly. Based on available end spacing, increasing the flaring between strands within each conductor-pair would eliminate machining the slot into the strands, allowing for inner-cooling of strands by not interfering with their internal coolant channel. An almost limitless variety of tips **135**, **145** may be fabricated within the scope of this invention.

[43] Once in place next to each other, the general goal of assembly is to connect each of these mated half-diamond coils **130**, **140** with each other, for example with a series connector that provides multiple current loops within each diamond coil. As described above, in the past, the conductors of these stator sections **105**, **107** might be brazed, welded or otherwise affixed in a semi-permanent or permanent fashion. While these prior methods may sufficiently interconnect the stator sections **105**, **107** for use, they also promote many problems. For example, these methods require specialized tools, knowledge and training to perform the welding or other connection necessary for installation.

This wastes both time and money. Second, when a stator section must be replaced or otherwise disassembled, the entire machine must be broken down by destroying the permanent or semi-permanent connections. Additionally, the various tools involved may be quite expensive or not available at some sites.

[44] In at least one preferred embodiment, therefore, the present invention provides a device and method for connecting these successive stator sections **105**, **107** to each other with an easily installed and removable connector **200** that provides sufficient usage characteristics under varied conditions. Even if the conductors within the stator are at different electrical potentials (e.g., 1-30 kV at 20-30,000 amps), the connector **200** can be designed to tolerate these harsh and varied operating conditions.

[45] **FIG. 11** details exemplary bolted series connectors **200** for use with the present invention to interconnect the upper **130** and lower **140** half-diamond coils while maintaining proper isolation between the various conductor-pairs. These connections must be made while retaining electrical isolation from each conductor-pair to all other conductor-pairs in a given half-diamond coil in the case where conductor-pairs consist of successive series turns of the coil and thus are at different voltage potentials. Specifically, **FIGS. 11A-E** detail multiple views of a bolted electrical connector **201** for interconnecting four conductor-pairs from each of the upper **130** and lower **140** half-diamond coils. **FIGS. 11F-J** details multiple views of a bolted electrical connector **202** for interconnecting four conductor-pairs from the upper half-diamond coil **130**

with three conductor pairs from the lower half-diamond coil **140**, with an additional phase lead interconnect jumper **203** for connection to a successive coil conductor (or machine neutral or line potentials).

[46] The constitution of the bolted series connector **201** will be described in detail, but the description applies to the connector **202**, with the difference being the phase lead **203** to interconnect to the next full diamond coil. The bolted series connector consists of an interleaved series of conductive and dielectric layers that interconnect the conductors of the upper **130** and lower **140** half-diamond coils to complete a full-diamond coil circuit. The electrical circuit connections are made from upper **130** to lower **140** half-diamond coils with machined copper jumper strap conductors **210**.

[47] Specifically, there are conductive strand layers **205** (shown through section C-C in **FIG. 11C**) at the location where each of the half-diamond coil tips **135** are inserted into the bolted connector **201**. Each conductive layer **205** is machined (clamp area **207**) to accept the profile of the tips **135** (see **FIG. 11C**). The outer three conductive layers **205** on the upper and lower parts of the connector **201** are electrically connected by copper jumper strap conductors **210** and the inside layer electrical connection is made through an inner layer jumper block **215**. Through these conductor layers **205** and jumper straps **215**, the conductors of the lower half-diamond coil **140** (attached to the bottom of connector **201**, see **FIG. 7B**) are connected to the conductors of the upper half-diamond coil **130** (attached to the top of connector **201**, see **FIG. 7B**). Once connectors **201**, **202** are applied to each end of the upper and lower half-

diamond coils (**FIG. 7B**), the connections mimic a conventional full-diamond coil **110** (**FIG. 3**).

- [48] Contact resistance controls the electrical losses and heat generated at the interfaces between these various conductive items. Silver plating of all mating copper contact surface areas limits the electrical contact resistance by inhibiting formation of high resistance surface oxides while the torque from the tightening bolt **220** minimizes resistance due to insufficient surface contact pressure.
- [49] The required insulation and resulting circuit isolation between conductive strand layers **205** is obtained by separating successive conductive layers with dielectric spacers **230**. These dielectric spacers **230** (shown in detail through cross-section B-B in **FIG. 11B**) are sized such that they extend beyond the conductive layers **205** (see **232**). The dielectric spacers may be made of a epoxy glass such as G10. Along the same lines, an insulating tube **235** and dielectric washer insulate the tightening bolt **220** and provide electrical isolation from the electrical circuit in the conductive layers **205** and jumper straps **210**.
- [50] After the conductive **205** and insulating **230** layers are properly aligned to the tips **135**, **145**, of the upper and lower half-diamond coils, a tightening bolt **220** is run through the layers and the holes **137** in the tips to secure the connector **201**, **202** together. The tightening bolt **220** load and resulting stretch is reacted by a self-locking heli-coil nut **225**. The bolt stretch required to maintain low contact resistance is provided for by the correct selection of bolt material, diameter

and installation torque. With proper sizing, heat-treated carbon steel, silicon bronze, and stainless steel bolt material can be used. Adequate long-term maintenance of bolt stretch is maintained by the proper sizing of the "Bellville" washer **227** located under the head of the bolt **220**. Once the bolt **220**, is installed, the connections are complete.

- [51] Once several connectors are installed on the stators, the insulation between successive bolted series connectors **200** and between bolted series connectors and other conductive surfaces in the machine is provided by covering or encasing each connector **200** in a molded (e.g., .040" thick) silicone rubber boot **250** as shown in **FIG. 12**. Other boot **250** materials and/or thicknesses could be used based on a particular machine's voltage rating and clearances between surfaces of different electrical potentials. The connectors **200** may be painted with an epoxy enamel before encasing them in the boot for greater insulation.
- [52] The boot **250** is preferably comprised of two mated rubber half-boots that are brought together around the connector **200** during installation. Preferably, the boot **250** is filled with a paste-like insulator or dielectric that, when cured, will further insulate the electrical conductors from each other. RTV may be included to reduce moisture. The two sections of the boot **250** may be secured to each other around the bolted electrical connector **200** using ordinary twist ties.
- [53] The connectors **200** may be built layer by layer at the installation site and completed by threading and tightening the bolt. Alternatively, the connector may

be pre-built and attached to the upper and lower half-diamond coils in an almost "snap-on" configuration. Typically, the bolt will still need to be tightened to a proper torque.

[54] As referenced above, **FIG. 7** shows top (**7A**) and side (**7B**) views of the upper **130** and lower **140** half-diamond coils connected together with bolted series connectors **200** (compare to the full-diamond coil of **FIG. 3**). When a connector **201** is connected to the left side of the half-diamond coils and a connector **202** (with phase lead **203**) is connected on the right side of the half-diamond coils, the combined structure simulates a full-diamond coil (**FIG. 3**).

[55] Further, **FIG. 9** shows an isometric view of first **105** and second **107** stator sections connected together using the bolted series connectors **200** of the present invention (compare to **FIG. 2**). In **FIG. 9**, the connectors **200** are preferably four conductor connector **201** on one side and three conductor connector **202** (with phased lead) on the other side. The phase lead **203** may be a ferruled "I-beam" that allows for easy interconnection with leads **147** of subsequent coil sections.

[56] Finally, **FIG. 10** includes a schematic drawing of current flow through the conductors of the upper **130** and lower **140** half-diamond coils when connected together using a bolted series connector **200** according to a preferred embodiment of the present invention. Note that the current enters the coil structure through leads **147**, makes four clockwise circuits through the coil structure, and exits through phased lead **203** (to be connected to the next coil structure).

- [57] High efficiency electrical machines benefit from transposition of strand layers (conductor-pairs) within each phase group. As an alternative embodiment, a Roebel transposition could be incorporated into the aforementioned bolted series connector **200** shown in **FIG. 11**. For example, the crossover circuit could be incorporated into the outer layer jumper straps **210** and into the inner layer jumper block **215** according to conventional practices. An additional plane for the jumper straps **210** would be required. When viewed from **FIG. 4**, the top layer of strands in the upper half-diamond coil **130** would be connected to the second from the bottom layer of strands of the connecting lower half-diamond coil **140**. The balance of the conductors would be connected in a comparable displacement pattern.
- [58] When properly fabricated and installed according to the above embodiment, the present invention provides a compact, compression-style bolted joint eliminating the need for semi-permanent metals joining processes such as welding, brazing, or soldering. Electrical separation spacing is maintained between components at different electrical potentials (e.g., in series windings). Conductive strands can be positively latched in place within the connector. Machine load requirements are easily met (e.g., a one-quarter inch diameter Grade 8 Carbon Steel bolt at 150 inch-pounds torque provides more than 10 times the 300 pound load required to safely conduct the 1553 amp coil current in common machines). A common G-10 insulator (used for dielectric washer and spacers in **FIG. 11**) provides mechanical creep (estimated over 50 years) that is less than the bolt is stretched. Belleville washers provide additional insurance against loss of contact pressure. A stainless steel self-

locking heli-coil nut assures no bolt loosening. A high quality dielectric molded silicon rubber boot may be used to fully insulate each connector assembly.

[59] These materials and designs allow for efficient assembly (virtually "snap-together" in some embodiments), disassembly, and maintenance of electrical machinery without the use of semi-permanent welded, brazed, soldered, riveted, and similar metals joining processes. They also facilitate connection of multiple electrical circuits using a single fastener and maintain electrical strike and creep integrity between electrical circuits of different voltage potentials. When compared to prior designs, the present invention also minimizes the physical space required to make single multi-strand connections and allows for the incorporation of electrical Roebel transpositions within the connector.

[60] Note that the foregoing discussion was based on interconnection of half diamond coils consisting of four series turns (or layers) to satisfy the machine's voltage rating requirements, with each layer (conductor-pair) consisting of two parallel strands to satisfy the machine's current rating requirements (**FIG. 4**). However, the concept of the connector configuration is not restricted to this particular combination of coil layers or strand parallels.

[61] Nothing in the above description is meant to limit the present invention to any specific materials, geometry, or orientation of elements. Many part/orientation substitutions are contemplated within the scope of the present invention and will be apparent to those skilled in the art. The embodiments described herein were

presented by way of example only and should not be used to limit the scope of the invention.

[62] Although the invention has been described in terms of particular embodiments in an application, one of ordinary skill in the art, in light of the teachings herein, can generate additional embodiments and modifications without departing from the spirit of, or exceeding the scope of, the claimed invention. Accordingly, it is understood that the drawings and the descriptions herein are proffered only to facilitate comprehension of the invention and should not be construed to limit the scope thereof.